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Diurnal Variation of Marine Stratocumulus over San Nicolas Island during the FIRE IFO

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1. Introduction

Preliminary analysis has been made of data collected at San Nicolas Island during the Intensive Field Observation (IFO) phase of the First International Satellite Cloud Climatology Program's Regional Experiment (FIRE). Of particular interest has been an examination of a distinct diurnal variation in the cloud properties, despite an apparent absence of diurnal forcing from the surface. Direct or indirect radiative modulation of such clouds, as proposed by Fravalo *et al.* (1981) and Turton and Nicholls (1987) indeed seems likely.

In this paper, preliminary observational evidence for diurnal change in the marine stratocumulus adjacent to San Nicolas Island is presented. A comparison is then made between the observed behavior and predictions from theoretical models of the interactive effect of radiation on boundary layer clouds.

2. Data Analysis

Preliminary analysis of the data collected by the San Nicolas Island participants[1] during the IFO period of July 1–19, 1988 indicates the presence of a relatively persistent stratocumulus cloud deck, modified by mild synoptic-scale variations. The first order effect of these variations on the values presented below has been removed by considering the local time departures from 24-hr running means. Error bars indicate the expected error in the mean local time departure at the 1 σ level, based on the observed natural variability during the data collection period.

Column liquid water, determined from the NOAA/WPL radiometer (Hogg *et al.*, 1983), is shown as a function of local time in Fig. 1. A diurnal signature is clearly discernible, with a maximum value of 0.13 mm in early morning falling steadily to a minimum of 0.02 mm in late afternoon before rising again to its early morning maximum.

Equally evident is the systematic diurnal variation in the cloud base height, obtained from the CSU ceilometer (Schubert *et al.*, 1987), shown in Fig. 2. Coincidental with maximum column liquid water, the cloud base drops to a minimum height of about 450 m above sea level in early morning and rises to a maximum of about 630 m by late afternoon.

Continuous time series of cloud top height had not been released at the time of this writing, so that cloud top height had to be determined from the much sparser CLASS radiosonde data. These are shown similarly in Fig. 3, and give the appearance of a consistent diurnal variation, with cloud top reaching a maximum height of about 820 m in early morning and a minimum of about 660 m in late afternoon.

Despite the noise present in the derived values of cloud thickness, presented in Fig. 4, the data are consistent with the presence of a diurnal trend in cloud thickness. Consistent with Fig. 1, maximum cloud thickness of about 400 m occurs in early morning and reduces to a minimum of about 150 m by late afternoon.

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[1]see acknowledgments for a list of data sources.

Similarly, the average liquid-water density within the cloud, obtained by dividing the column amount by the cloud thickness, as shown in Fig. 5, is too noisy to unequivocally confirm a diurnal variation. However Fig. 5 is consistent with an average liquid water density ranging from 0.5 g m^{-3} in early morning to 0.2 g m^{-3} in late afternoon.

The relationship between average liquid water density and cloud thickness may be clearer in Fig. 6, which shows strong positive correlation between these variables.

3. Discussion

The clear diurnal signature in column liquid water content of the marine stratocumulus adjacent to San Nicolas Island during the FIRE IFO indicates some degree of radiative modulation of the cloud. Despite noisy values of cloud top height that will be improved once more data is released to the FIRE science team, estimates of the diurnal variation of cloud thickness can be made. The initial analysis reveals a systematic lowering of cloud top and raising of cloud base from around sunrise to around sunset, with the reverse during nighttime. As the cloud thickness decreases during the day, so too does the mean liquid water density in the cloud, and together these effects combine to produce the observed signature in column liquid water.

We are presently examining explanations for this behavior, in conjunction with theoretical models of cloud-radiative interaction, and will relate the model predictions to measurements of drop size distributions within the cloud once these also are made available.

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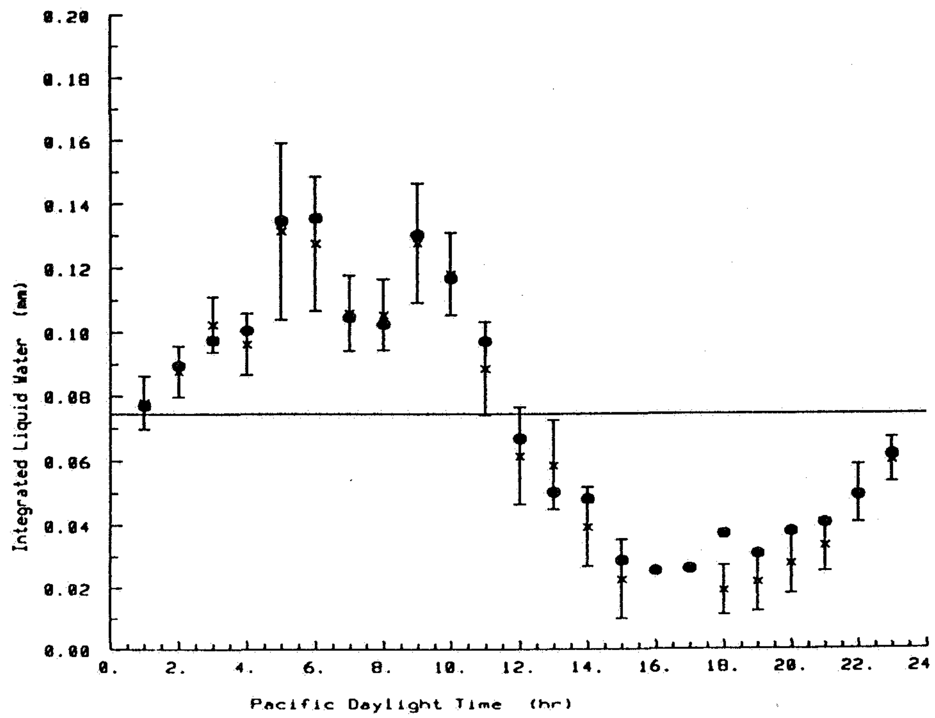

FIG. 1. Column liquid water versus local time, determined from the NOAA/WPL radiometer on San Nicolas Island. Circles - averages over the observing period. Crosses - averages after removing synoptic trends. Error bars indicate uncertainty in individual mean values based on natural variability.

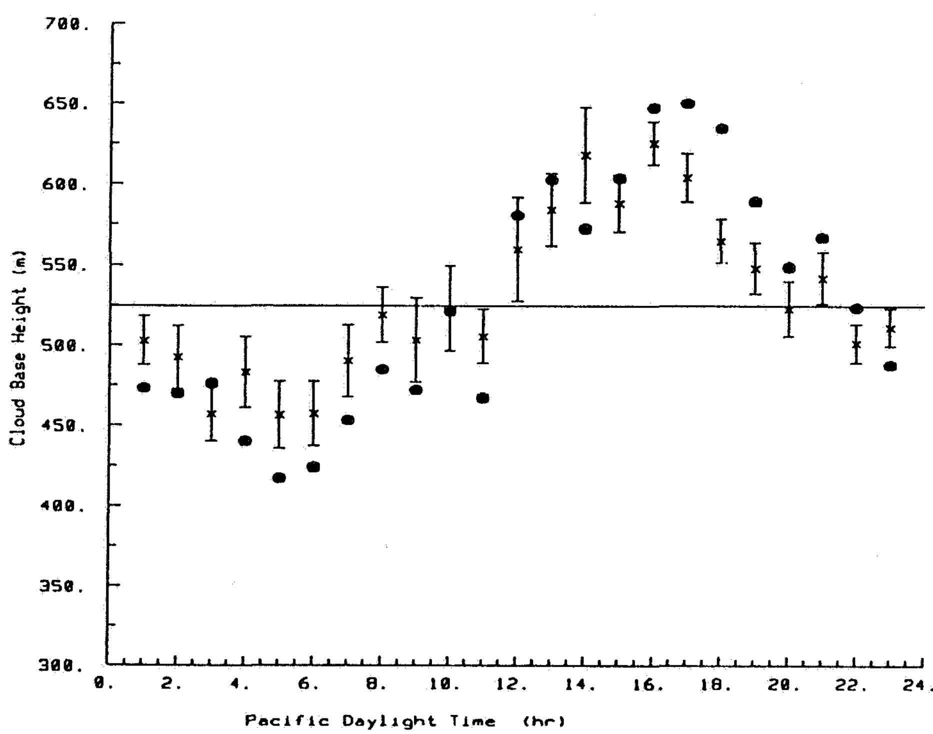

FIG. 2. Cloud base height versus local time. Symbols as in Fig. 1.

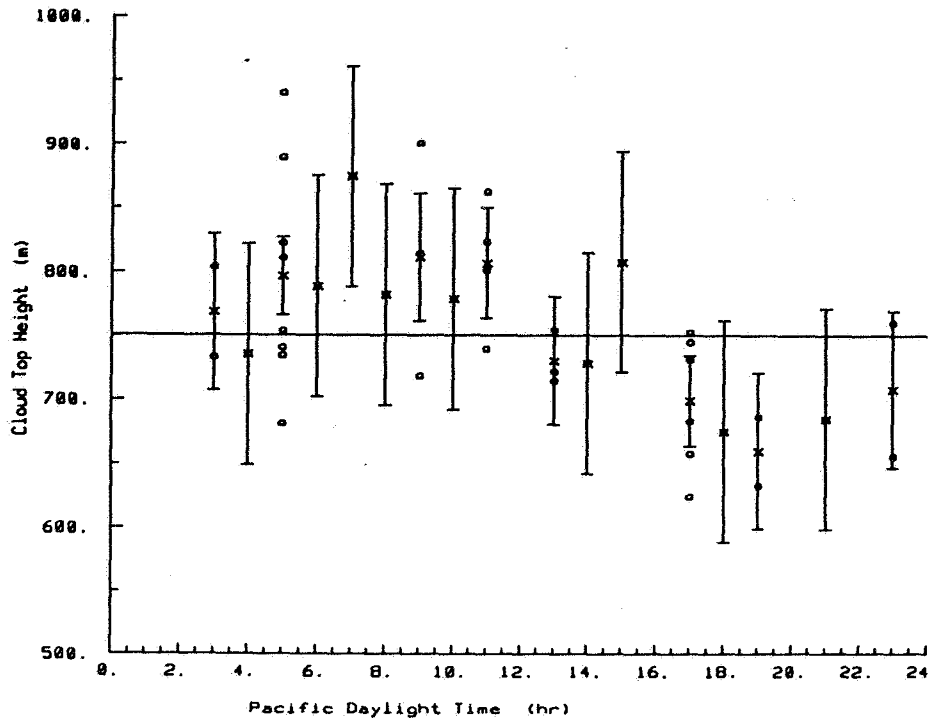

FIG. 3. Cloud top height from radiosonde data, after removal of synoptic trends. Open circles- individual data points. Crosses- mean values. Error bars indicate uncertainty in mean values based on variance of data at 0500 PDT.

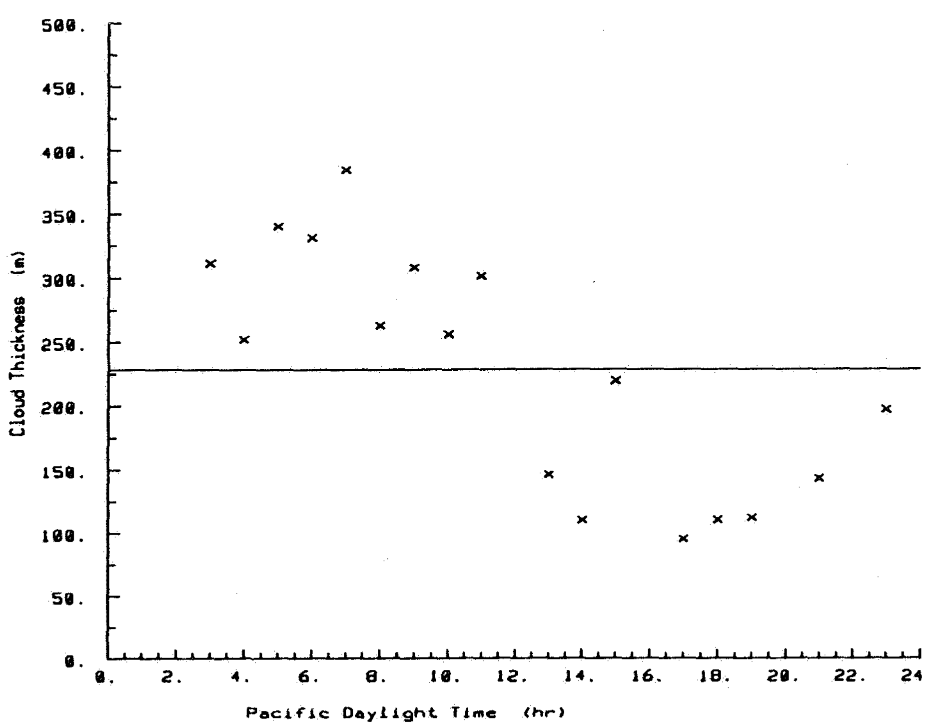

FIG. 4. Cloud thickness versus local time, obtained by differencing Fig. 3 and Fig. 2.

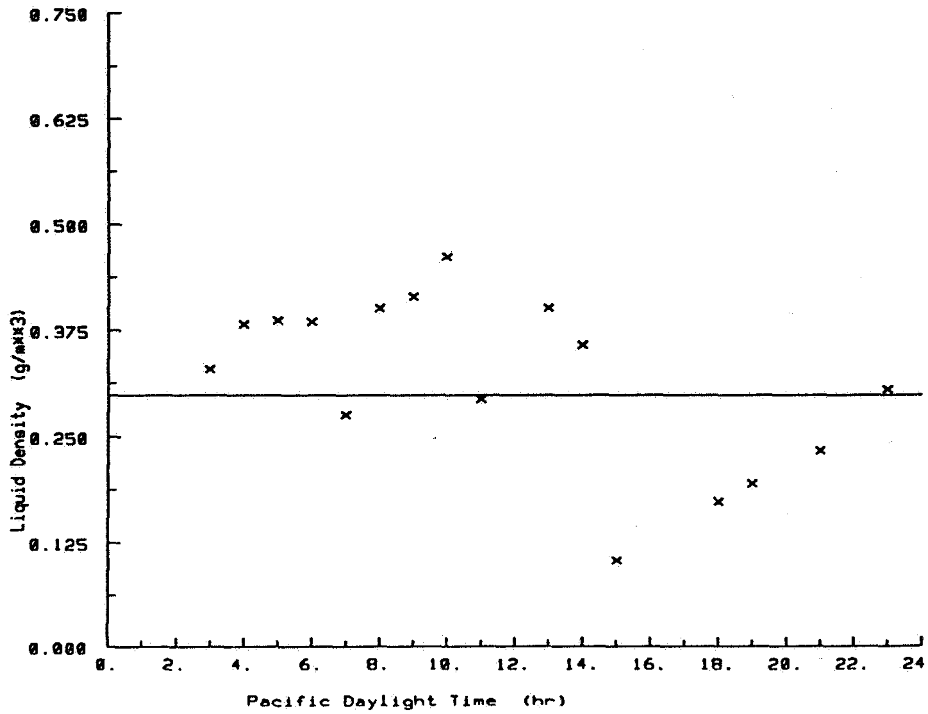

Fig. 5. Average cloud liquid water density versus local time, obtained by combining data from Fig. 1 and Fig. 4.

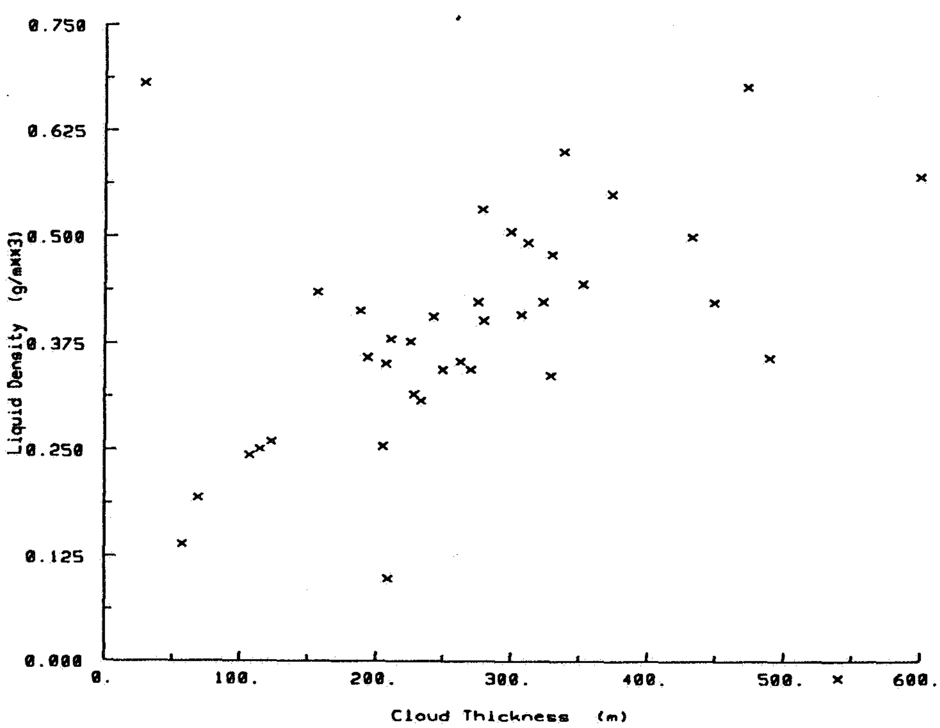

Fig. 6. Scatter diagram of average cloud liquid water density versus cloud thickness, using data coincident with radiosonde determination of cloud top height.